ENERGY ENGINEERING ANALYSIS PROGRAM

ENERGY SURVEY OF ARMY BOILER & CHILLER PLANTS

AT

Fort Knox, Kentucky

FINAL REPORT

MARCH 1993

VOLUME I

EXECUTIVE SUMMARY

Prepared For:

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DEPARTMENT OF THE ARMY
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NOTE: ***In accordance with the Scope of Work, Appendix G - Field Data Forms, was submitted only with the Interim Submittal of this report.***

ABBREVIATIONS

A	Amps
BHP	Boiler Horse Power
BPO	Back Pull Out Pump Configuration, allows Impeller Service without Disturbing Piping Connections
BTU	British Thermal Unit
CC Cent.	Close Coupled, End Suction Centrifugal Pump
CHW Lvg.	Chilled Water Temperature in °F Leaving the Chiller Heat Exchanger
CHW Ent.	Chilled Water Temperature in °F Entering the Chiller Heat Exchanger
CHW	Chilled Water
CO_2	Carbon Dioxide
DA	Deaerator
DB	Dry Bulb Temperature, Ordinary Air Temperature
ECO	Cooling Tower, Two Speed Fan Analysis
EMCS	Energy Management and Control System
ES Cent.	End Suction Centrifugal Pump
F	Temperature in Degrees Fahrenheit
FD	Forced Draft
FLA	Full Load Amps
FT WC	Unit of Pressure, Feet of Water Column, Equal to .433 PSI

GPM	Gallons Per Minute
(H)	Honeywell Combustion Data
H-O-A	Three Position, Hand-Off Automatic, Control Switch providing On, Off, and Automatic Operation of the Equipment Switched
HW	Hot Water
ID	Induced Draft
kW	kiloWatts
MBH	Thousand BTU Per Hour
N_2	Nitrogen
(O)	Orsat Combustion Data
O_2	Oxygen
PF	Power Factor, Ratio of Actual Electrical Power to Apparent Power; i.e, Actual Watts/(Volts x Amps). Specifically the Cosine of the Phase Angle between Volts and Amps.
PPH	Pounds Per Hour
PRV	Pressure Reducing Valve
PSIG	Pounds Per Square Inch, Gage
RLA	Running Load Amps
(T)	Teledyne Combustion Data
V-3PH	Voltage in Three Phase Circuit
WB	Wet Bulb Temperature, Temperature of Water in Equilibrium with Ambient Air, Obtained by Exposing a Moistened Wick to Ambient Air.

EXECUTIVE SUMMARY

1.0 INTRODUCTION

1.1 BACKGROUND:

This is the final report of an Energy Engineering Analysis Program (EEAP) study of boilers and chillers at Fort Knox, Kentucky. In September 1990, work was begun on the project by BENATECH, INC. under Contract No. DACA27-90-T-0080, with the Louisville District, U.S. Army Corps of Engineers. The following activities have been accomplished:

- Detailed field investigations have been conducted.
- ECO calculations have been performed and life-cycle analyses have been accomplished.
- Programming documentation has been prepared based on guidance provided by the Louisville District COE.
- Final report is complete and submitted for review.

1.2 SCOPE:

The Scope of Work specified in Contract No. DACA27-90-T-0080 (included in this report in Appendix A) requires the performance of a detailed energy study. The energy conservation opportunities analyzed under this study will serve as part of the overall effort at Ft. Knox to reduce basewide energy use in accordance with the objectives set forth in the Army Energy Program. The contract Scope of Work (SOW) for Ft. Knox outlines the following specific requirements.

- Determine the efficiency of the boiler/chiller plants by appropriate tests.

- Survey the boiler/chiller plants to determine if efficiency can be improved by the repair, addition, or modification of equipment and recommend improvements.

- Evaluate the control system and recommend upgrading, adjustment, repair, or replacement of controls which will improve the efficiency of the plant.

- Review operations and maintenance practices and provide recommendations which will increase plant efficiency.

- Prepare a comprehensive report to document the work performed, results, and recommendations.

2.0 BOILER PLANT DATA

Figure ES2-1 provides a listing of the thirteen boilers addressed by this study and summarizes boiler efficiency test results.

FIGURE ES2-1

BOILER PLANT DATA

BLDG #	BOILER #	BOILER MAKE	BOILER CAPACITY	BOILER MODEL (Or Size Type)	CALCULATED EFFICIENCY (At Test Conditions)
852	1	Vogt	35,000 PPH	VF	69.8%
	2	Vogt	35,000 PPH	VF	69.5%
	3	Vogt	35,000 PPH	VF	70.9%
5943	1	LaMont	26,000 MBH	LFW 12.5	84.0%
	2	LaMont	26,000 MBH	LFW 12.5	83.7%
6580	1	Burnham	6,900 PPH	3P-200-50	78.6%
	2	Burnham	6,900 PPH	3P-200-50	76.4%
	3	Burnham	2,760 PPH	3P-80-50	84.4%
2780	1 (L)	Titusville	12,000 PPH	HRT	66.5%
	2 (R)	Titusville	12,000 PPH	HRT	63.7%
1486	1	Superior	4,312 PPH	4-5-625	80.8%
	2	Superior	4,312 PPH	4-5-625	80.7%
1725	1	International	12,000 PPH	IDH-19	66.1%

3.0 CHILLER PLANT DATA

Figure ES3-1 provides a listing of the fifty-three chiller plants addressed by this study and summarizes chiller efficiency test results.

FIGURE ES3-1

CHILLER PLANT DATA

PLANT #	BLDG #	BLDG CHILLER #	CHILLER MANUFACTURER	CHILLER MODEL #	UNIT TYPE	RATED TONS	TEST TONS	TEST kW/TON
1	296	CH-1	TSI	20A0CD70S	ACX	66	48	1.66
2	297	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	28 34	2.20 1.57
3	298	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	38 58	1.40 1.17
4	853	CH-1	Trane	RAUA10006R0	ACX	100	18	2.28
5	1117	CH-1	Trane	CGADC50GACA	ACC	50	24	1.40
6	1118	CH-1	Trane	CCABD10GRAN	ACR	100	73	1.69
7	1468	CH-1	TSI	SE2CS36	ACX	30	15	2.67
8	1474	CH-1	TSI	20ACM120S	ACX	104	38	1.73
9	1475	CH-1 CH-2	Trane Trance	RAUA6006EA RAUA6006EA	ACX ACX	60 60	-- 35	Inoperative 1.38
10	1479	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	27 --	2.67 Inoperative
11	1482	CH-1	Trane	RAUA100AF002	ACX	100	35	1.70
12	1483	CH-1 CH-1&2	TSI (See Note 1)	20ACM120S	ACX	52 104	36 93	0.91 1.03
13	1484	CH-1&2	TSI (See Note 1)	20ACM120S	ACX	104	85	1.46
14	1485	CH-1 CH-1&2	TSI (See Note 1)	20A0CM140S	ACX	66 132	16 64	1.90 1.92
15	1486	CH-1&2	TSI (See Note 1)	20A0CM140S	ACX	132	99	1.11
16	1720	CH-1	D-B	AC105A	ACC	105	40	2.06

Figure ES3 - 1 (1 of 4)

FIGURE ES3 - 1

CHILLER EFFICIENCY TESTING RESULTS

PLANT #	BLDG #	BLDG CHILLER #	CHILLER MANUFACTURER	CHILLER MODEL #	UNIT TYPE	RATED TONS	TEST TONS	TEST kW/TON
17	2373	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	-- 23	Inoperative 2.03
18	2374	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	-- 38	Inoperative 1.37
19	2375	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	21 47	2.54 1.30
20	2376	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	-- 35	Inoperative 1.36
21	2377	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	-- 36	Inoperative 1.86
22	2378	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	52 --	1.17 Inoperative
23	2379	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	-- 33	Inoperative 1.38
24	2380	CH-1 CH-2	Trane Trane	RAUA6006EA RAUA6006EA	ACX ACX	60 60	-- 27	Inoperative 1.94
25	2381	CH-1	Trane	RAU6006EA	ACX	60	19	2.10
26	2385	CH-1	Trane	CGACC6006KBN	ACX	60	34	1.32
27	2724	CH-1	McQuay	ALP085AD	ACC	85	19	2.36
28	4249	CH-1	McQuay	ALR060C	ACC	60	38	1.19
29	4250	CH-1	McQuay	ALR060C	ACC	60	53	1.18
30	4770	CH-1 CH-2	Trane Trane	CGACD201EBN CGACD201EBN	ACC ACC	200 200	73 66	1.60 1.72

Figure ES3 - 1 (2 of 4)

FIGURE ES3 - 1

CHILLER EFFICIENCY TESTING RESULTS

PLANT #	BLDG #	BLDG CHILLER #	CHILLER MANUFACTURER	CHILLER MODEL #	UNIT TYPE	RATED TONS	TEST TONS	TEST kW/TON
31	5101	CH-1 CH-2	Trane TSI	CGWA0406MB51 CA2CD75	ACR ACC	40 69	16 69	1.35 0.81
32	5916	CH-1	Trane	CG75C	WCC	75	39	1.14
33	5917	CH-1	Trane	CG75C	WCC	75	34	1.96
34	5918	CH-1	Trane	CG75C	WCC	50	21	1.32
35	5919	CH-1	Trane	CG75C	WCC	75	53	1.06
36	5920	CH-1	Trane	CG75C	WCC	75	52	1.00
37	5921	CH-1	Trane	CG75C	WCC	75	35	1.19
38	5922	CH-1	Trane	CG75C	WCC	75	59	1.10
39	5940	CH-1	McQuay	C808	WCC	80	64	0.92
40	5942	CH-1	Carrier	30AA400119	WCC	40	21	1.65
41	5949	CH-1	Trane	CGADC50GACA	ACC	50	42	1.39
42	6010	CH-1	Trane	CG75C	WCC	75	34	1.27
43	6011	CH-1	Trane	CG75C	WCC	75	34	0.93
44	6012	CH-1	D-B	WC8100	WCC	80	71	0.99
45	6015	CH-1	Trane	CG75C	WCC	75	64	0.83
46	6017	CH-1	Trane	CG75C	WCC	75	60	0.98
47	6289	CH-1	Trane	CGACC606	ACC	60	25	1.68
48	6544	COMP #2 COMP #1	TSI See Note 1	20A0CD90S	ACX	82	31 33	1.01 1.24

Figure ES3 - 1 (3 of 4)

FIGURE ES3 - 1

CHILLER EFFICIENCY TESTING RESULTS

PLANT #	BLDG #	BLDG CHILLER #	CHILLER MANUFACTURER	CHILLER MODEL #	UNIT TYPE	RATED TONS	TEST TONS	TEST kW/TON
49	6553	CH-1	McQuay	ALP080C	ACX	80	63	1.02
50	6554	CH-1 CH-2	TSI	20A0CM120S See Note 1	ACX	52 52	-- 25	Inoperative 1.32
51	6590	CH-1 CH-2	D-B Trane	CDRD1279B2R	WCC WCC	80 80	70 --	1.04 Inoperative
52	6597	CH-1	Trane	CGADC60GABA	ACC	60	63	1.02
53	9261	CH-1 CH-2	Trane Trane	CCACC806RDN CCACC806RDN	ACR ACR	80 80	48 --	0.88 Incomplete

UNIT TYPE

ACX = Air cooled, outdoor, reciprocating compressor/condenser unit with mechanical room refrigerant/CHW heat exchanger.

ACR = Indoor reciprocating chiller with outdoor air cooled condensing unit.

ACC = Air cooled, outdoor, packaged reciprocating chiller.

WCC = Water cooled chiller, condenser pump, cooling tower.

NOTES

1. Chillers manufactured by TSI, Models 90, 120, and 140 are two independent chillers in a single sheet metal housing. Power supplies to the two systems are independent, and power to the chillers was measured independently. Where possible, data for independent operation is listed. Typically, the compressor operating sequence permitted only combined readings.

2. Inoperative means that chiller was inoperative at the time of the survey.

3. Incomplete means that the installation of the chiller was incomplete as of the date of the survey.

Figure ES3 - 1 (4 of 4)

4.0 PRESENT ENERGY CONSUMPTION

4.1 BOILERS:

Figure ES4-1 summarizes current annual energy consumption by the thirteen boilers in the scope of this study.

FIGURE ES4-1

PRESENT ENERGY CONSUMPTION AND COST BY BOILERS

BLDG #	BOILER #	TEST EFFICIENCY	CURRENT ANNUAL FUEL CONSUMPTION	CURRENT ANNUAL FUEL COST
852	1	75.7	683,100 therms	$211,761
	2	76.4	676,800 therms	$209,808
	3	77.0	671,500 therms	$208,165
5943	1	84.0	187,970 gallons	$193,609
	2	83.7	188,600 gallons	$194,258
6580	1	78.6	98,500 therms	$30,535
	2	78.4	98,700 therms	$30,597
	3	84.4	24,100 therms	$7,471
2780	1	66.5	107,200 therms	$33,232
	2	63.7	111,900 therms	$34,689
1486	1	80.8	131,100 therms	$40,641
	2	80.7	131,200 therms	$40,672
1725	1	66.1	154,062 therms	$47,759
		TOTALS	**2,888,162 therms natural gas** **376,570 gallons #2 fuel oil**	**$1,283,197**

4.2 CHILLERS:

Figure ES4-2 summarizes current annual energy consumption by the fifty-three chiller plants in the scope of this study.

FIGURE ES4 - 2

PRESENT ENERGY CONSUMPTION AND COST BY CHILLERS

PLANT #	BLDG #	ESTIMATED CFLH/YR	TEST KW/TON	OPERATING TONS	PLANT KW	CURRENT KWH/YR	CURRENT ANNUAL COST
1	296	1,333	1.66	66	110	146,043	$8,077
2	297	1,333	1.57	60	94	125,569	$6,945
3	298	1,333	1.17	60	70	93,577	$5,175
4	853	1,333	2.28	100	228	303,924	$16,809
5	1117	1,333	1.40	50	70	93,310	$5,161
6	1118	1,600	1.69	100	169	270,400	$13,588
7	1468	1,333	2.67	30	80	106,773	$5,905
8	1474	1,333	1.73	104	180	239,833	$13,265
9	1475	1,333	1.38	60	83	110,372	$6,104
10	1479	1,333	2.67	60	160	213,547	$11,811
11	1482	1,333	1.70	100	170	226,610	$12,533
12	1483	1,333	1.03	104	107	142,791	$7,897
13	1484	1,333	1.46	104	152	202,403	$11,194
14	1485	1,333	1.92	132	253	337,836	$18,685
15	1486	1,333	1.11	132	147	195,311	$10,802
16	1720	1,600	2.06	105	216	346,080	$17,391
17	2373	1,333	2.03	60	122	162,359	$8,980
18	2374	1,333	1.37	60	82	109,573	$6,060
19	2375	1,333	1.30	60	78	103,974	$5,751
20	2376	1,333	1.36	60	82	108,773	$6,016
21	2377	1,333	1.86	60	112	148,763	$8,228
22	2378	1,333	1.17	60	70	93,577	$5,175
23	2379	1,333	1.38	60	83	110,372	$6,104
24	2380	1,333	1.94	60	116	155,161	$8,582
25	2381	1,333	2.10	60	126	167,958	$9,289
26	2385	1,600	1.32	60	79	126,720	$6,368
27	2724	1,600	2.36	85	201	320,960	$16,128

Figure ES4-2 (1 of 2)

FIGURE ES4 - 2

PRESENT ENERGY CONSUMPTION AND COST BY CHILLERS

PLANT #	BLDG #	ESTIMATED CFLH/YR	TEST KW/TON	OPERATING TONS	PLANT KW	CURRENT KWH/YR	CURRENT ANNUAL COST
28	4249	1,184	1.19	60	71	84,538	$4,998
29	4250	1,184	1.18	60	71	83,827	$4,956
30	4770	1,333	1.60	200	320	426,560	$23,592
31	5101	1,600	0.81	69	56	89,424	$4,494
32	5916	1,333	1.14	75	86	113,972	$6,303
33	5917	1,333	1.96	75	147	195,951	$10,838
34	5918	500	1.32	50	66	33,000	$3,491
35	5919	1,333	1.06	75	80	105,974	$5,861
36	5920	1,333	1.00	75	75	99,975	$5,529
37	5921	1,333	1.19	75	89	118,970	$6,580
38	5922	1,333	1.10	75	83	109,973	$6,082
39	5940	1,333	0.92	80	74	98,109	$5,426
40	5942	1,333	1.65	40	66	87,978	$4,866
41	5949	1,600	1.39	50	70	111,200	$5,588
42	6010	1,333	1.27	75	95	126,968	$7,022
43	6011	1,333	0.93	75	70	92,977	$5,142
44	6012	1,333	0.99	80	79	105,574	$5,839
45	6015	1,333	0.83	75	62	82,979	$4,589
46	6017	1,333	0.98	75	74	97,976	$5,419
47	6289	1,600	1.68	60	101	161,280	$8,104
48	6544	1,333	1.01	82	83	110,399	$6,106
49	6553	1,333	1.02	80	82	108,773	$6,016
50	6554	1,333	1.32	52	69	91,497	$5,060
51	6590	1,600	1.04	80	83	133,120	$6,689
52	6597	1,333	1.02	60	61	81,580	$4,512
53	9261	1,600	0.88	80	70	112,640	$5,660
					TOTALS	**7,827,780**	**$426,789**

Figure ES4-2 (2 of 2)

5.0 ENERGY CONSERVATION ANALYSIS

5.1 ECOS INVESTIGATED:

The Scope of Work contains a list of specific ECOs to be studied for Fort Knox boilers and chillers. These ECOs were investigated after completing our field survey visits and compiling the raw data from the visits. The steps in collecting the field data were:

- Obtain nameplate data and methods of operation for the boilers and chillers.

- Inspect types and conditions of control systems.

- Take field measurements on boilers and chillers.

Using the field data, the various ECOs were analyzed for feasibility of being implemented under Army guidelines.

A list of ECOs evaluated is shown below. This list includes ECOs shown in Annex A of the contract Scope of Work and additional ECOs identified by BENATECH, INC.

- *Controls to Assure Proper Combustion Air-Fuel Ratio*
- *Feedwater Treatment*
- *Waste Heat Recovery; i.e., Exhaust Gases, Process Steam Pressure Drop, and Steam Condensate and Blowdown*
- *Installation of New Burner Equipment*
- *Economizers/Air Pre-Heaters*
- *Reduce Excess Air*
- *Loading Characteristics and Scheduling Versus Equipment Capacity (Equipment Optimization)*

- *Variable Speed Circulation Pumps or Alternate Pumps Based on Seasonal Loading*
- *Steam Pressure or Hot Water Temperature Reductions Based on Seasonal Loading and/or Existing and Projected Requirements*
- *Reductions in Make-Up Water Quantities*
- *Control Systems to Operate Chillers at Their Most Energy Efficient Operating Condition*
- *Blowdown Control*
- *Prevent Air Leakage*
- *Condenser/Cooling Tower Water Treatment*
- *Variable or Two-Speed Cooling Tower Fan*
- *Free Cooling Cycles in Lieu of Chiller Operation*
- *Storage of Chilled Water*
- *High Efficiency Motors*
- *Steam Driven Auxiliaries Versus Electric Drives*
- *Variable Speed Induced Draft Fans and Forced Draft Blowers*
- *Instruments and Controls to Facilitate Efficient Operations*
- *Use Smaller Boilers Where Load has Been Reduced*
- *Automatic Chiller Tube Cleaners*
- *Correct Sizing of Traps*
- *Replace Inefficient Boilers with More Efficient Boilers*

5.1.1 BOILER ECO DESCRIPTIONS:

Boiler Feedwater Economizer

This ECO investigates the energy savings achievable by preheating the boiler feedwater with recovered waste heat from the flue gas.

Burner Replacement

This ECO analyzes the energy savings achievable by replacing existing burners with modulating, cam-type burners. These burners modulate the air-to-fuel ratio as a function of boiler load. This modulation results in a combustion efficiency of approximately 80% over the operating range of the boiler.

Boiler Tune-Up

The boiler should be tuned for minimum excess air at their respective average operating loads. Ft. Knox boiler maintenance staff already perform quarterly tune-ups on all boilers.

Pre-Heat Combustion Air

The purpose of this ECO is to use waste heat recovered from the flue gas to preheat combustion air.

"Summer" Boiler

This ECO analyzes the potential of installing a boiler to handle the steam production requirements during the "summer" months. Available consumption data was examined to isolate the steam capacity requirements for each month. The "summer" boilers were then sized to meet average summer loads. The energy savings are realized in the increased efficiency of the new boilers (approximately 80%) as compared with the underloaded (during summer operations) existing boilers.

Variable-Speed Motor Drives

This ECO analyzes the potential for savings by installing inverters on combustion air fan motors. Inverters save energy by controlling the fan power in response to actual air flow requirements.

Boiler Replacement

This ECO evaluates the savings to be achieved by replacing the existing boiler with a new, high efficiency boiler of the same size.

Downsize Boilers

Existing boilers do not appear to be oversized for their respective loads, except for those which carry "summer" loads. See description of "Summer Boiler".

Installation of Turbulators

This ECO analyzes the energy savings achievable by installing turbulators in fire-tube boilers. Turbulators are baffles which create turbulent flow in the core of hot combustion gases. This turbulent flow maximizes heat transfer from combustion gases through the tube walls to the boiler water. Thus, more heat is used in the generation of steam and less is lost out the exhaust stack. This ECO is not applicable to water-tube boilers.

Oxygen Trim System/Controls to Assure Proper Combustion Air-Fuel Ratio

The purpose of an oxygen trim system is to control the air/fuel ratio of a boiler within the most efficient operating parameters. This is achieved by using an oxygen analyzer in the flue stack in conjunction with a microprocessor controller. The oxygen analyzer measures the oxygen content in the flue gas and a potentiometer monitors the fuel flow rate. The microprocessor controls adjust the air flow damper in order to get the most efficient combustion process.

Feedwater Treatment

This measure is addressed in Section 3, O&Ms.

Waste Heat Recovery

This ECO is covered by three approaches: economizers, air pre-heaters, and blowdown heat recovery.

Reduce Excess Air

This ECO is addressed in Section 3, O&Ms.

Equipment Optimization

This ECO is addressed in Section 3, O&Ms.

Variable Speed Circulation Pumps

Only one boiler plant--No. 5943, a hot water plant--has circulation pumps. Study of system distribution was not within the scope of this project.

Steam Pressure or Hot Water Temperature Reductions Based on Seasonal Loading and/or Existing and Project Requirements

This ECO is addressed in Section 3, O&Ms.

Reductions in Make-up Water Quantities/Blowdown Control

This ECO is addressed in the "Automatic Blowdown/Blowdown Heat Recovery ECO".

High Efficiency Motors

This ECO analyzes the savings to be achieved by replacing existing standard efficiency motors with premium efficiency motors.

Steam Driven Auxiliaries

Current operating pressures versus distribution pressures do not yield a pressure drop significant enough to make this ECO feasible.

Correct Sizing of Traps

All steam traps observed during field surveys appeared to be correctly sized for the respective applications.

5.1.2 CHILLER ECO DESCRIPTIONS:

Automatic Chiller Tube Cleaning

This ECO establishes representative savings which result form the installation of an on-line condenser tube cleaning system. This system uses slightly oversized brushes fitted into each condenser tube to remove rust and deposits. The brushing action is initiated by a diverted valve, which changes the direction of water flow, pushing the brushes to either end of the condenser. Flow through the condenser automatically changes. Savings result from improved heat transfer from the condenser water through the condenser tube wall.

Chiller Shutdown/EMS Tie-In

This ECO analyzes the energy savings achievable when equipment is operated only when it is needed to provide comfort conditioning. The savings are calculated for chillers (partially loaded), chilled water, and condenser water pumps, and cooling towers. This ECO is accomplished by tying the plant into existing basewide energy management system (EMS).

Chilled Water Temperature Reset

This ECO analyzes the energy savings resulting from resetting the chilled water supply temperature upward, without appreciable affecting comfort conditions. Savings result from decreasing the demand on the chiller compressor, and therefore, the amount of energy input to the chiller. This ECO is accomplished using the existing EMS.

Water Treatment

This ECO is addressed in Section 3, O&Ms.

Waterside Economizer/Free Cooling

This ECO evaluates the feasibility of installing a plate heat exchanger, new valves, and controls to enable the chiller to be shutdown during periods of the year when the wet bulb temperatures will provide sufficient evaporative cooling effect. Building load fluctuates with internal and external loads. During the fall, winter, and spring, the external cooling loads on a building are at a minimum or nonexistent. During these seasons, the wet bulb temperatures are low enough to maintain evaporation in sufficient quantity to provide condenser water cold enough to meet the internal loads of the building.

Variable Speed Pumping

This ECO is actually a "reduced speed" pumping analysis, whereby chilled water pumps are re-sized based on actual chiller plant loads.

Two Speed Cooling Tower Fan Motors

This ECO examines the energy savings resulting from replacing the constant speed cooling tower fan motor with a two speed motor. Savings result from the fan law which states that the power required to operate a fan varies as the cube of the fan speed.

Replace Inefficient Chillers

This ECO evaluates the electrical energy savings achievable by replacing existing chillers with new high-efficiency chillers. Field surveys indicated that typical chiller operating conditions were approximately 82°F outside air temperature and 52°F leaving chiller water temperature. At these conditions, reciprocating chillers kW/ton would be about 95% of the ARI values. Following is a list of chiller types and corresponding adjusted efficiencies used in the ECO calculations:

ACX - Air cooled, outdoor, reciprocating compressor/condenser unit with mechanical room refrigerant/CHW heat exchanger. New chiller kW/ton = 0.91.

ACR - Indoor reciprocating chiller with outdoor air cooled condensing unit. New chiller kW/ton = 0.92.

ACC - Air cooled, outdoor, packaged reciprocating chiller. New chiller kW/ton = 0.93.

WCC - Water cooled chiller, condenser pump, cooling tower. New chiller kW/ton = 0.75.

Chilled Water Pump Shutdown

Currently, even when the chillers are shutdown (during unoccupied periods) by the basewide EMS, the chilled water pumps run continuously. This ECO evaluates the savings to be achieved by shutting down the chilled water pumps with the chillers, using the EMS.

High Efficiency Motors

This ECO was evaluated for all chiller plant motors. Because of relatively short annual hours of operation of these motors, all projects have SIRs < 1.0. Sample analyses were provided for one of each type of motor (Appendix E).

Waste Heat Recovery

This ECO evaluates the savings to be achieved by recovering chiller waste heat to make domestic hot water.

Chilled Water Storage

This ECO analyzes the savings to be achieved by generating chilled water during off-peak hours. Also analyzed is ice storage.

5.1.3 RESULTS OF ECOS INVESTIGATED:

A summary of all boiler ECO results is shown in Figure ES5.1-1. A summary of all chiller ECO results is shown in Figure ES5.1-2.

FIGURE ES5.1 - 1

BOILER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	BOILER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	PAGE #
BLOWDOWN HEAT RECOVERY	852	19,845	15,744	1.3	11.00	F - 167
HEAVY OIL CONVERSION	5943	276,916	159,841	1.7	8.06	F - 163
OXYGEN TRIM SYSTEM	5943-2	21,186	5,663	3.7	4.47	F - 137
TURBULATOR INSTALLATION	1486-1	1,573	611	2.6	3.74	F - 1
TURBULATOR INSTALLATION	1486-2	1,573	611	2.6	3.74	F - 4
OXYGEN TRIM SYSTEM	5943-1	21,186	3,938	5.4	3.11	F - 134
TURBULATOR INSTALLATION	6580-1	1,954	459	4.3	2.26	F - 16
TURBULATOR INSTALLATION	6580-2	1,954	459	4.3	2.26	F - 19
TURBULATOR INSTALLATION	1725-1	3,507	716	4.9	1.97	F - 7
BLOWDOWN HEAT RECOVERY	2780	13,427	1,698	7.9	1.75	F - 176
OXYGEN TRIM SYSTEM	2780-1	21,186	2,013	10.5	1.62	F - 128
BLOWDOWN HEAT RECOVERY	1486	19,845	2,033	9.8	1.44	F - 170
TURBULATOR INSTALLATION	2780-2	3,507	521	6.7	1.43	F - 13
TURBULATOR INSTALLATION	2780-1	3,507	499	7.0	1.37	F - 10
OXYGEN TRIM SYSTEM	1725-1	21,186	1,644	12.9	1.33	F - 125
OXYGEN TRIM SYSTEM	2780-2	21,186	1,546	13.7	1.25	F - 131
BLOWDOWN HEAT RECOVERY	1725	15,442	1,194	12.9	1.07	F - 173
TURBULATOR INSTALLATION	6580-3	1,016	112	9.1	1.06	F - 22
BLOWDOWN HEAT RECOVERY	6580	23,797	1,715	13.9	1.00	F - 179
ENERGY EFFICIENT MOTORS	1486	564	45	12.6	0.91	F - 37
OXYGEN TRIM SYSTEM	6580-1	21,186	1,119	18.9	0.90	F - 140
BOILER REPLACEMENT	1725-1	183,815	8,298	22.2	0.77	F - 90
ECONOMIZER INSTALLATION	1725-1	24,671	1,318	18.7	0.74	F - 148
BOILER REPLACEMENT	2780-2	183,815	7,069	26.0	0.66	F - 96
ENERGY EFFICIENT MOTORS	1486	507	27	18.9	0.61	F - 33
ENERGY EFFICIENT MOTORS	852	1,654	88	18.8	0.61	F - 29
ENERGY EFFICIENT MOTORS	852	1,288	68	19.0	0.60	F - 25
OXYGEN TRIM SYSTEM	1486-2	21,186	724	29.3	0.59	F - 123

Figure ES5.1-1 (1 of 2)

FIGURE ES5.1 - 1

BOILER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	BOILER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	PAGE #
OXYGEN TRIM SYSTEM	1486-1	21,186	683	31.0	0.55	F - 120
BOILER REPLACEMENT	2780-1	183,815	5,608	32.8	0.52	F - 93
ENERGY EFFICIENT MOTORS	6580	564	23	24.6	0.47	F - 77
ENERGY EFFICIENT MOTORS	5943	676	27	25.3	0.46	F - 65
ENERGY EFFICIENT MOTORS	5943	1,113	41	27.4	0.42	F - 61
BOILER REPLACEMENT	852-1	501,313	11,382	44.0	0.39	F - 81
BURNER REPLACEMENT	2780-1	71,616	2,027	35.3	0.39	F - 117
BOILER RESIZING	852	1,312,964	28,601	45.9	0.37	F - 160
ENERGY EFFICIENT MOTORS	5943	3,664	62	58.7	0.36	F - 69
ENERGY EFFICIENT MOTORS	1725	564	17	33.8	0.34	F - 41
BOILER REPLACEMENT	852-2	501,313	9,442	53.1	0.32	F - 84
BURNER REPLACEMENT	1725-1	71,616	1,528	46.9	0.30	F - 114
ENERGY EFFICIENT MOTORS	5943	2,518	65	40.0	0.29	F - 73
ENERGY EFFICIENT MOTORS	2780	676	17	39.5	0.29	F - 53
BOILER REPLACEMENT	852-3	501,313	7,807	64.2	0.27	F - 87
ENERGY EFFICIENT MOTORS	2780	1,113	26	42.7	0.27	F - 49
BURNER REPLACEMENT	2780-2	71,616	1,284	55.8	0.25	F - 117
ENERGY EFFICIENT MOTORS	1725	507	10	50.7	0.23	F - 45
BURNER REPLACEMENT	852-2	162,330	2,308	70.3	0.20	F - 108
BURNER REPLACEMENT	852-1	162,330	2,329	69.7	0.20	F - 105
AIR PREHEATER	1725-1	84,891	1,318	64.4	0.19	F - 154
ENERGY EFFICIENT MOTORS	2780	507	8	63.3	0.18	F - 57
SUMMER BOILER	1486	51,027	197	259.0	0.07	F - 157
BOILER REPLACEMENT	6580-1	165,463	534	309.9	0.06	F - 99
BOILER REPLACEMENT	6580-2	165,463	612	270.4	0.06	F - 102
ECONOMIZER INSTALLATION	1486-1	20,220	88	229.8	0.06	F - 145
OXYGEN TRIM SYSTEM	6580-3	21,186	10	2118.6	0.01	F - 143
AIR PREHEATER	1486-1	84,891	88	964.7	0.01	F - 151

Figure ES5.1-1 (2 of 2)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHW PUMP SHUTDOWN/EMS	1485	202	446	0.5	21.56	E - 83
CHW PUMP SHUTDOWN/EMS	1486	202	446	0.5	21.56	E - 88
CHW PUMP SHUTDOWN/EMS	1482	202	446	0.5	21.56	E - 73
CHW PUMP SHUTDOWN/EMS	1483	202	446	0.5	21.56	E - 78
CHW PUMP SHUTDOWN/EMS	298	202	446	0.5	21.56	E - 43
CHW PUMP SHUTDOWN/EMS	1479	202	446	0.5	21.56	E - 68
CHW PUMP SHUTDOWN/EMS	2374	202	446	0.5	21.56	E - 98
CHW PUMP SHUTDOWN/EMS	2380	202	446	0.5	21.56	E -118
CHW PUMP SHUTDOWN/EMS	2373	202	446	0.5	21.56	E - 93
CHW PUMP SHUTDOWN/EMS	2375	202	446	0.5	21.56	E -103
CHW PUMP SHUTDOWN/EMS	1474	202	446	0.5	21.56	E - 58
CHW PUMP SHUTDOWN/EMS	1475	202	446	0.5	21.56	E - 63
CHW PUMP SHUTDOWN/EMS	297	202	446	0.5	21.56	E - 38
CHW PUMP SHUTDOWN/EMS	2377	202	446	0.5	21.56	E -108
CHW PUMP MOTOR RESIZING	1483	564	999	0.6	20.23	E -642
CHW PUMP MOTOR RESIZING	2374	564	995	0.6	20.14	E -667
CHW PUMP MOTOR RESIZING	1475	564	995	0.6	20.14	E -632
CHW PUMP MOTOR RESIZING	2380	564	995	0.6	20.14	E -697
CHW PUMP MOTOR RESIZING	297	564	995	0.6	20.14	E -612
CHW PUMP MOTOR RESIZING	2375	564	995	0.6	20.14	E -672
CHW PUMP MOTOR RESIZING	298	564	995	0.6	20.14	E -617
CHW PUMP MOTOR RESIZING	2376	564	995	0.6	20.14	E -677
CHW PUMP MOTOR RESIZING	2373	564	995	0.6	20.14	E -662
CHW PUMP MOTOR RESIZING	2379	564	995	0.6	20.14	E -692
CHW PUMP MOTOR RESIZING	2377	564	995	0.6	20.14	E -682

Figure ES5.1-2 (1 of 8)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHW PUMP MOTOR RESIZING	6289	564	992	0.6	20.08	E -742
CHW PUMP MOTOR RESIZING	1485	564	991	0.6	20.06	E -652
CHW PUMP MOTOR RESIZING	1482	564	973	0.6	19.70	E -637
CHW PUMP MOTOR RESIZING	1474	564	971	0.6	19.66	E -627
CHW PUMP MOTOR RESIZING	1484	564	971	0.6	19.66	E -647
CHW PUMP MOTOR RESIZING	1486	564	956	0.6	19.35	E -657
CHW PUMP MOTOR RESIZING	2378	564	652	0.8	14.68	E -687
CHW PUMP SHUTDOWN/EMS	5942	202	302	0.7	14.60	E -173
CHW PUMP SHUTDOWN/EMS	2378	202	302	0.7	14.60	E -113
CHW PUMP SHUTDOWN/EMS	6389	202	302	0.7	14.60	E -203
CHW PUMP SHUTDOWN/EMS	5940	202	302	0.7	14.60	E -168
CHW PUMP SHUTDOWN/EMS	2381	202	230	0.9	11.12	E -123
CHW PUMP SHUTDOWN/EMS	296	202	230	0.9	11.12	E - 33
CHW PUMP SHUTDOWN/EMS	853	202	230	0.9	11.12	E - 48
CHW PUMP SHUTDOWN/EMS	5917	202	230	0.9	11.12	E -138
CHW PUMP MOTOR RESIZING	6554	507	485	1.0	10.92	E -752
CHW PUMP MOTOR RESIZING	6544	507	469	1.1	10.56	E -747
CHW PUMP MOTOR RESIZING	1468	564	326	1.2	9.23	E -622
CHW PUMP SHUTDOWN/EMS	5918	202	191	1.1	9.23	E -143
CHW PUMP MOTOR RESIZING	5922	404	302	1.3	8.55	E -722
CHW PUMP MOTOR RESIZING	5916	404	302	1.3	8.55	E -702
CHW PUMP MOTOR RESIZING	6010	404	302	1.3	8.55	E -727
CHW PUMP MOTOR RESIZING	6015	404	302	1.3	8.55	E -737
CHW PUMP MOTOR RESIZING	5920	404	302	1.3	8.55	E -712
CHW PUMP MOTOR RESIZING	5921	404	302	1.3	8.55	E -717

Figure ES5.1-2 (2 of 8)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHW PUMP MOTOR RESIZING	5919	404	302	1.3	8.55	E -707
CHW PUMP MOTOR RESIZING	6011	404	302	1.3	8.55	E -732
CHW PUMP SHUTDOWN/EMS	5922	202	155	1.3	7.49	E -163
CHW PUMP SHUTDOWN/EMS	5919	202	155	1.3	7.49	E -148
CHW PUMP SHUTDOWN/EMS	5916	202	155	1.3	7.49	E -133
CHW PUMP SHUTDOWN/EMS	6017	202	155	1.3	7.49	E -198
CHW PUMP SHUTDOWN/EMS	1468	202	155	1.3	7.49	E - 53
CHW PUMP SHUTDOWN/EMS	6011	202	155	1.3	7.49	E -188
CHW PUMP SHUTDOWN/EMS	6015	202	155	1.3	7.49	E -193
CHW PUMP SHUTDOWN/EMS	5921	202	155	1.3	7.49	E -158
CHW PUMP SHUTDOWN/EMS	6010	202	155	1.3	7.49	E -283
CHW PUMP SHUTDOWN/EMS	5920	202	155	1.3	7.49	E -153
CHILLER SHUTDOWN/EMS	1118	3,006	2,026	1.5	6.58	E - 1
CHILLER SHUTDOWN/EMS	6012	3,006	1,570	1.9	5.10	E - 25
CHILLER SHUTDOWN/EMS	1720	3,006	1,296	2.3	4.21	E - 5
CHILLER WASTE HEAT REC.	1720	7,549	2,289	3.3	4.20	E -507
CHILLER WASTE HEAT REC.	1485	7,549	2,234	3.4	4.10	E -497
CHILLER WASTE HEAT REC.	2724	7,549	2,122	3.6	3.90	E -562
CHILLER WASTE HEAT REC.	1118	7,549	1,788	4.2	3.28	E -457
CHILLER SHUTDOWN/EMS	5101	3,006	926	3.2	3.01	E - 21
CHILLER WASTE HEAT REC.	1474	7,549	1,586	4.8	2.91	E -467
CHILLER SHUTDOWN/EMS	4250	3,006	874	3.4	2.84	E - 17
CHILLER SHUTDOWN/EMS	9261	3,006	860	3.5	2.79	E - 29
CHILLER WASTE HEAT REC.	1482	7,549	1,499	5.0	2.75	E -482
CHW PUMP SHUTDOWN/EMS	6590	202	54	3.7	2.61	E -208

Figure ES5.1-2 (3 of 8)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHILLER SHUTDOWN/EMS	2724	3,006	801	3.8	2.60	E - 9
CHILLER WASTE HEAT REC.	1479	7,549	1,412	5.3	2.59	E -477
CHILLER WASTE HEAT REC.	1484	7,549	1,338	5.6	2.46	E -492
CHILLER WASTE HEAT REC.	1486	7,549	1,292	5.8	2.37	E -502
CHILLED WATER RESET	296	936	219	4.3	2.28	E -757
CHILLER SHUTDOWN/EMS	4249	3,006	704	4.3	2.28	E - 13
CHW PUMP SHUTDOWN/EMS	5949	202	44	4.6	2.13	E -178
CHW PUMP SHUTDOWN/EMS	2385	202	44	4.6	2.13	E -128
CHILLER WASTE HEAT REC.	2381	7,549	1,111	6.8	2.04	E -552
CHILLER WASTE HEAT REC.	2373	7,549	1,074	7.0	1.97	E -512
CHILLER WASTE HEAT REC.	6289	7,549	1,066	7.1	1.96	E -582
CHILLED WATER RESET	297	936	188	5.0	1.96	E -761
CHILLED WATER RESET	853	936	182	5.1	1.90	E -769
CHILLER WASTE HEAT REC.	2380	7,549	1,026	7.4	1.88	E -547
CHILLER WASTE HEAT REC.	2377	7,549	984	7.7	1.81	E -532
CHILLER WASTE HEAT REC.	296	7,549	966	7.8	1.77	E -437
CHILLER WASTE HEAT REC.	1483	7,549	944	8.0	1.73	E -487
CHILLER WASTE HEAT REC.	2385	7,549	838	9.0	1.54	E -557
CHILLER WASTE HEAT REC.	297	7,549	830	9.1	1.53	E -442
CHILLED WATER RESET	1474	936	144	6.5	1.50	E -777
CHILLED WATER RESET	298	936	140	6.7	1.46	E -765
CHILLED WATER RESET	1482	936	136	6.9	1.42	E -789
REPLACEMENT CHILLER	1479	55,946	7,785	7.2	1.36	E -273
CHILLER WASTE HEAT REC.	5949	7,549	735	10.3	1.35	E -577
CHILLER WASTE HEAT REC.	2379	7,549	730	10.3	1.34	E -542

Figure ES5.1-2 (4 of 8)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHILLER WASTE HEAT REC.	1475	7,549	730	10.3	1.34	E -472
CHILLER WASTE HEAT REC.	6544	7,549	730	10.3	1.34	E -587
CHILLER WASTE HEAT REC.	2374	7,549	725	10.4	1.33	E -517
CHILLED WATER RESET	1479	936	128	7.3	1.33	E -785
CHILLER WASTE HEAT REC.	6553	7,549	719	10.5	1.32	E -592
CHILLER WASTE HEAT REC.	2376	7,549	719	10.5	1.32	E -527
CHILLER WASTE HEAT REC.	1468	7,549	706	10.7	1.30	E -462
REPLACEMENT CHILLER	2724	74,157	9,773	7.6	1.29	E -337
CHILLER WASTE HEAT REC.	2375	7,549	688	11.0	1.26	E -522
CHILLED WATER RESET	1484	936	121	7.7	1.26	E -797
CHILLED WATER RESET	5917	936	118	8.0	1.23	E -849
CHILLED WATER RESET	1486	936	117	8.0	1.22	E -805
REPLACEMENT CHILLER	1468	32,563	3,893	8.4	1.17	E -261
CHILLER WASTE HEAT REC.	2378	7,549	619	12.2	1.14	E -537
CHILLER WASTE HEAT REC.	9261	7,549	621	12.2	1.14	E -607
CHILLER WASTE HEAT REC.	298	7,549	619	12.2	1.14	E -447
CHILLER WASTE HEAT REC.	1117	7,549	617	12.2	1.13	E -452
CHILLER WASTE HEAT REC.	6554	7,549	605	12.5	1.11	E -597
REPLACEMENT CHILLER	1720	91,900	9,539	9.6	1.09	E -293
REPLACEMENT CHILLER	853	91,900	10,100	9.1	1.07	E -249
CHILLED WATER RESET	2381	936	101	9.3	1.05	E -841
CHILLED WATER RESET	1485	936	100	9.3	1.04	E -801
CHILLER WASTE HEAT REC.	4249	7,549	559	13.5	1.03	E -567
CHILLER WASTE HEAT REC.	4250	7,549	554	13.6	1.02	E -572
CHILLED WATER RESET	2373	936	97	9.6	1.01	E -809

Figure ES5.1-2 (5 of 8)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHILLER WASTE HEAT REC.	6597	7,549	539	14.0	0.99	E -602
REPLACEMENT CHILLER	5942	26,300	2,654	9.9	0.98	E -385
CHILLED WATER RESET	2380	936	93	10.1	0.97	E -837
CHILLED WATER RESET	2377	936	89	10.5	0.93	E -825
REPLACEMENT CHILLER	2381	55,946	5,264	10.6	0.92	E -329
REPLACEMENT CHILLER	2373	55,946	4,954	11.3	0.86	E -297
ENERGY EFFICIENT MOTORS	1118	789	58	13.7	0.84	E -225
ENERGY EFFICIENT MOTORS	296	676	49	13.8	0.83	E -213
REPLACEMENT CHILLER	2380	55,946	4,556	12.3	0.79	E -325
CHILLED WATER RESET	6010	936	76	12.3	0.79	E -873
ENERGY EFFICIENT MOTORS	297	1,113	75	14.9	0.77	E -217
ENERGY EFFICIENT MOTORS	1117	564	38	14.8	0.77	E -221
CHILLED WATER RESET	5921	936	71	13.1	0.74	E -865
REPLACEMENT CHILLER	2377	55,946	4,202	13.3	0.73	E -313
REPLACEMENT CHILLER	1485	66,372	4,817	13.8	0.71	E -285
CHILLED WATER RESET	5916	936	68	13.7	0.71	E -845
CHILLED WATER RESET	2374	936	66	14.2	0.69	E -813
CHILLED WATER RESET	5922	936	66	14.2	0.69	E -869
CHILLED WATER RESET	2379	936	66	14.1	0.69	E -833
CHILLED WATER RESET	1475	936	66	14.1	0.69	E -781
CHILLED WATER RESET	2376	936	65	14.3	0.68	E -821
CHILLED WATER RESET	5919	936	64	14.7	0.67	E -857
CHILLED WATER RESET	1468	936	64	14.6	0.67	E -773
REPLACEMENT CHILLER	1474	91,900	6,287	14.6	0.67	E -265
REPLACEMENT CHILLER	1118	91,900	6,191	14.8	0.66	E -257

Figure ES5.1-2 (6 of 8)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHILLED WATER RESET	2375	936	62	15.0	0.65	E -817
REPLACEMENT CHILLER	6010	43,977	2,875	15.3	0.64	E -393
REPLACEMENT CHILLER	1482	91,900	5,824	15.8	0.62	E -277
CHILLED WATER RESET	5920	936	60	15.6	0.62	E -861
REPLACEMENT CHILLER	6289	58,023	3,618	16.0	0.61	E -413
CHILLED WATER RESET	6011	936	56	16.8	0.58	E -877
CHILLED WATER RESET	2378	936	56	16.7	0.58	E -829
REPLACEMENT CHILLER	296	66,372	3,649	18.2	0.54	E -237
REPLACEMENT CHILLER	5921	43,977	2,433	18.1	0.54	E -373
REPLACEMENT CHILLER	4770	178,224	9,879	18.0	0.54	E -349
ENERGY EFFICIENT MOTORS	5101	507	23	22.1	0.52	E -233
CHILLED WATER RESET	6015	936	50	18.8	0.52	E -881
REPLACEMENT CHILLER	297	55,946	2,920	19.2	0.51	E -241
REPLACEMENT CHILLER	5917	43,977	2,156	20.4	0.48	E -357
REPLACEMENT CHILLER	5916	43,977	2,156	20.4	0.48	E -353
REPLACEMENT CHILLER	5918	30,407	1,508	20.2	0.48	E -361
REPLACEMENT CHILLER	1484	91,900	4,217	21.8	0.45	E -281
REPLACEMENT CHILLER	5922	43,977	1,935	22.7	0.43	E -377
CHILLED WATER RESET	1483	936	138	24.7	0.40	E -793
REPLACEMENT CHILLER	5919	43,977	1,714	25.7	0.38	E -365
REPLACEMENT CHILLER	5949	48,990	1,930	25.4	0.38	E -389
REPLACEMENT CHILLER	6590	46,338	1,710	27.1	0.36	E -429
REPLACEMENT CHILLER	2379	55,946	2,079	26.9	0.36	E -321
REPLACEMENT CHILLER	1475	55,946	2,079	26.9	0.36	E -269
REPLACEMENT CHILLER	1117	48,990	1,733	28.3	0.35	E -253

Figure ES5.1-2 (7 of 8)

FIGURE ES5.1 - 2

CHILLER ECO RESULTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
REPLACEMENT CHILLER	2376	55,946	1,991	28.1	0.35	E -309
REPLACEMENT CHILLER	2374	55,946	2,035	27.5	0.35	E -301
WATERSIDE ECONOMIZER	SAMPLE	2,300	92	25.0	0.35	E -885
ENERGY EFFICIENT MOTORS	2385	404	12	34.9	0.34	E -229
REPLACEMENT CHILLER	2385	55,946	1,978	28.3	0.34	E -333
REPLACEMENT CHILLER	6554	47,323	1,572	30.1	0.32	E -425
REPLACEMENT CHILLER	5920	43,977	1,382	31.8	0.31	E -369
REPLACEMENT CHILLER	6012	46,338	1,416	32.7	0.30	E -401
REPLACEMENT CHILLER	2375	55,946	1,725	32.4	0.30	E -305
REPLACEMENT CHILLER	6017	43,977	1,272	34.6	0.28	E -409
VARIABLE SPEED FAN	SAMPLE	2,300	60	38.0	0.23	E -892
REPLACEMENT CHILLER	6011	43,977	995	44.2	0.22	E -397
REPLACEMENT CHILLER	1486	85,281	1,946	43.8	0.22	E -289
REPLACEMENT CHILLER	5940	46,338	1,003	56.2	0.21	E -381
CHILLED WATER RESET	5918	936	20	47.3	0.21	E -853
REPLACEMENT CHILLER	2378	55,946	1,150	48.6	0.20	E -317
REPLACEMENT CHILLER	298	55,946	1,150	48.6	0.20	E -245
REPLACEMENT CHILLER	4250	58,023	1,050	55.3	0.18	E -345
REPLACEMENT CHILLER	4249	58,023	1,092	53.1	0.18	E -341
CHILLED WATER STORAGE	SAMPLE	172,800	3,504	49.0	0.16	E -896
AUTOMATIC TUBE CLEANERS	SAMPLE	16,717	189	88.0	0.11	E -899
REPLACEMENT CHILLER	6015	43,977	442	99.4	0.10	E -405
REPLACEMENT CHILLER	6597	58,023	398	145.7	0.07	E -433
REPLACEMENT CHILLER	6553	91,900	649	141.7	0.07	E -421
REPLACEMENT CHILLER	6544	91,900	605	152.0	0.06	E -417

Figure ES5.1-2 (8 of 8)

5.2 ECOS RECOMMENDED:

As was shown in the previous section, results of all boiler and chiller ECO calculations are summarized in Figures ES5.1-1 and ES5.1-2. Recommended ECOs are those with savings-to-investment ratios (SIRs) greater than or equal to 1.0. These ECOs were then re-evaluated to include interaction with other recommended ECOs. Results were again summarized by SIR and revised ECOs with SIRs less than 1.0 were no longer recommended. Revised ECO calculations are included in Programming Documentation section in Volume IV, Appendix C. A final summary of recommended boiler ECOs (including interaction) is shown in Figure ES5.2-1. A final summary of recommended chiller ECOs (including interaction) is shown in Figure ES5.2-2.

FIGURE ES5.2-1

RECOMMENDED BOILER ECOS - SORTED BY SIR

ECO DESCRIPTION	BOILER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	PAGE #
BLOWDOWN HEAT REC.	852	19,845	15,744	1.3	11.00	F - 167
HEAVY OIL CONVERSION	5943	276,916	159,841	1.7	8.06	F - 163
OXYGEN TRIM SYSTEM	5943-2	21,186	5,663	3.7	4.47	F - 137
TURBULATOR INSTALL.	1486-1	1,573	611	2.6	3.74	F - 1
TURBULATOR INSTALL.	1486-2	1,573	611	2.6	3.74	F - 4
OXYGEN TRIM SYSTEM	5943-1	21,186	3,938	5.4	3.11	F - 134
TURBULATOR INSTALL.	6580-1	1,954	459	4.3	2.26	F - 16
TURBULATOR INSTALL.	6580-2	1,954	459	4.3	2.26	F - 19
TURBULATOR INSTALL.	1725-1	3,507	716	4.9	1.97	F - 7
BLOWDOWN HEAT REC.	2780	13,427	1,698	7.9	1.75	F - 176
OXYGEN TRIM SYSTEM	2780-1	21,186	2,013	10.5	1.62	F - 128
BLOWDOWN HEAT REC.	1486	19,845	2,033	9.8	1.44	F - 170
TURBULATOR INSTALL.	2780-2	3,507	521	6.7	1.43	F - 13
TURBULATOR INSTALL.	2780-1	3,507	499	7.0	1.37	F - 10
OXYGEN TRIM SYSTEM	1725-1	21,186	1,644	12.9	1.33	F - 125
OXYGEN TRIM SYSTEM	2780-2	21,186	1,546	13.7	1.25	F - 131
BLOWDOWN HEAT REC.	1725	15,442	1,194	12.9	1.07	F - 173
TURBULATOR INSTALL.	6580-3	1,016	112	9.1	1.06	F - 22
BLOWDOWN HEAT REC.	6580	23,797	1,715	13.9	1.00	F - 179
	TOTALS	**$493,793**	**$201,017**	2.5		

FIGURE ES5.2 - 2

RECOMMENDED CHILLER ECOS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
				(THERMS)	($)		
CHW PUMP SHUTDOWN/EMS	1479	202	17,826		446	0.5	21.56
CHW PUMP MOTOR RESIZING	2376	564	27,764		995	0.6	20.14
CHW PUMP MOTOR RESIZING	2379	564	27,764		995	0.6	20.14
CHW PUMP MOTOR RESIZING	6289	564	27,647		992	0.6	20.08
CHW PUMP MOTOR RESIZING	1482	564	27,375		973	0.6	19.70
CHW PUMP MOTOR RESIZING	1484	564	27,336		971	0.6	19.66
CHW PUMP SHUTDOWN/EMS	6389	202	12,070		302	0.7	14.60
CHW PUMP SHUTDOWN/EMS	5942	202	12,094		302	0.7	14.60
CHW PUMP SHUTDOWN/EMS	5940	202	12,094		302	0.7	14.60
CHW PUMP MOTOR RESIZING	1483	564	16,991		728	0.8	12.59
CHW PUMP MOTOR RESIZING	2380	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2375	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2373	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	298	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	297	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2374	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	1475	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2377	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	1485	564	16,855		720	0.8	12.45
CHW PUMP MOTOR RESIZING	1474	564	16,485		700	0.8	12.10
CHW PUMP MOTOR RESIZING	1486	564	16,213		685	0.8	11.84
CHW PUMP SHUTDOWN/EMS	5917	202	9,200		230	0.9	11.12
CHW PUMP SHUTDOWN/EMS	2381	202	9,200		230	0.9	11.12
CHW PUMP SHUTDOWN/EMS	296	202	9,200		230	0.9	11.12
CHW PUMP SHUTDOWN/EMS	853	202	9,200		230	0.9	11.12
CHW PUMP MOTOR RESIZING	6554	507	13,668		485	1.0	10.92
CHW PUMP MOTOR RESIZING	6544	507	13,376		469	1.1	10.56
CHW PUMP SHUTDOWN/EMS	5918	202	7,644		191	1.1	9.23
CHW PUMP MOTOR RESIZING	2378	564	11,081		471	1.1	9.06
CHW PUMP SHUTDOWN/EMS	1483	202	6,185		155	1.3	7.49

Figure ES5.2-2 (1 of 4)

FIGURE ES5.2 - 2

RECOMMENDED CHILLER ECOs - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
				(THERMS)	($)		
CHW PUMP SHUTDOWN/EMS	2380	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	297	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1474	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	6017	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2377	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2375	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	298	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1486	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1482	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1475	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2373	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2374	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1485	202	6,185		155	1.3	7.49
CHILLER SHUTDOWN/EMS	1118	3,006	81,051		2,026	1.5	6.58
CHW PUMP MOTOR RESIZING	1468	564	5,540		236	1.7	5.70
CHW PUMP MOTOR RESIZING	6011	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5919	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	6015	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5922	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	6010	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5921	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5920	404	5,103		211	1.9	5.10
CHILLER SHUTDOWN/EMS	6012	3,006	62,803		1,570	1.9	5.10
CHW PUMP MOTOR RESIZING	5916	404	5,103		211	1.9	5.10
CHW PUMP SHUTDOWN/EMS	2378	202	3,807		95	2.1	4.59
CHILLER WASTE HEAT REC.	1485	7,549		7,026	2,234	3.4	4.10
CHILLER SHUTDOWN/EMS	2724	3,006	41,738		1,252	2.4	4.06
CHW PUMP SHUTDOWN/EMS	6015	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5920	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5922	202	2,570		64	3.1	3.09

Figure ES5.2-2 (2 of 4)

FIGURE ES5.2 - 2

RECOMMENDED CHILLER ECOs - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
				(THERMS)	($)		
CHW PUMP SHUTDOWN/EMS	6010	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	1468	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	6011	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5919	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5916	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5921	202	2,570		64	3.1	3.09
CHILLER SHUTDOWN/EMS	5101	3,006	37,024		926	3.2	3.01
CHILLER WASTE HEAT REC.	1474	7,549		5,116	1,586	4.8	2.91
CHILLER SHUTDOWN/EMS	4250	3,006	24,453		874	3.4	2.84
CHILLER SHUTDOWN/EMS	9261	3,006	34,407		860	3.5	2.79
CHILLER WASTE HEAT REC.	1482	7,549		4,834	1,499	5.0	2.75
CHW PUMP SHUTDOWN/EMS	6590	202	2,175		54	3.7	2.61
CHILLER WASTE HEAT REC.	1484	7,549		4,318	1,338	5.6	2.46
CHILLER WASTE HEAT REC.	1486	7,549		4,116	1,292	5.8	2.37
CHILLED WATER RESET	296	936	8,763		219	4.3	2.28
CHILLER SHUTDOWN/EMS	4249	3,006	17,681		704	4.3	2.28
CHILLER WASTE HEAT REC.	1118	7,549		3,865	1,198	6.3	2.20
CHW PUMP SHUTDOWN/EMS	2385	202	1,740		44	4.6	2.13
CHW PUMP SHUTDOWN/EMS	5949	202	1,740		44	4.6	2.13
CHILLER WASTE HEAT REC.	2381	7,549		3,583	1,111	6.8	2.04
CHILLER WASTE HEAT REC.	2373	7,549		3,463	1,074	7.0	1.97
CHILLER WASTE HEAT REC.	6289	7,549		3,440	1,066	7.1	1.96
CHILLED WATER RESET	297	936	7,534		188	5.0	1.96
CHILLED WATER RESET	853	936	7,294		182	5.1	1.90
CHILLER WASTE HEAT REC.	2380	7,549		3,310	1,026	7.4	1.88
CHILLER WASTE HEAT REC.	2377	7,549		3,173	984	7.7	1.81
CHILLER WASTE HEAT REC.	296	7,549		3,115	966	7.8	1.77
CHILLER WASTE HEAT REC.	1483	7,549		3,046	944	8.0	1.73
CHILLER WASTE HEAT REC.	2385	7,549		2,703	838	9.0	1.54
CHILLER WASTE HEAT REC.	297	7,549		2,679	830	9.1	1.53

Figure ES5.2-2 (3 of 4)

FIGURE ES5.2 - 2

RECOMMENDED CHILLER ECOs - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS (THERMS)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR
CHILLED WATER RESET	1474	936	5,756		144	6.5	1.50
CHILLED WATER RESET	298	936	5,615		140	6.7	1.46
CHILLED WATER RESET	1482	936	5,439		136	6.9	1.42
REPLACEMENT CHILLER	1479	55,946	140,765		7,785	7.2	1.36
CHILLER WASTE HEAT REC.	5949	7,549		2,372	735	10.3	1.35
CHILLER WASTE HEAT REC.	6544	7,549		2,355	730	10.3	1.34
CHILLER WASTE HEAT REC.	2379	7,549		2,354	730	10.3	1.34
CHILLER WASTE HEAT REC.	1475	7,549		2,354	730	10.3	1.34
CHILLER WASTE HEAT REC.	2374	7,549		2,377	725	10.4	1.33
CHILLED WATER RESET	1479	936	5,125		128	7.3	1.33
CHILLER WASTE HEAT REC.	2376	7,549		2,320	719	10.5	1.32
CHILLER WASTE HEAT REC.	6553	7,549		2,320	719	10.5	1.32
CHILLER WASTE HEAT REC.	1720	7,549		2,233	692	10.9	1.27
CHILLED WATER RESET	1484	936	4,858		121	7.7	1.26
CHILLER WASTE HEAT REC.	2375	7,549		2,218	688	11.0	1.26
CHILLED WATER RESET	5917	936	4,703		118	8.0	1.23
CHILLED WATER RESET	1486	936	4,687		117	8.0	1.22
REPLACEMENT CHILLER	1468	32,563	70,382		3,893	8.4	1.17
CHILLER WASTE HEAT REC.	298	7,549		1,996	619	12.2	1.14
CHILLER WASTE HEAT REC.	2378	7,549		1,996	619	12.2	1.14
CHILLER WASTE HEAT REC.	1117	7,549		1,990	617	12.2	1.13
CHILLER WASTE HEAT REC.	6554	7,549		1,952	605	12.5	1.11
REPLACEMENT CHILLER	1720	91,900	189,840		9,539	9.6	1.09
REPLACEMENT CHILLER	853	91,900	182,621		10,100	9.1	1.07
REPLACEMENT CHILLER	2724	74,157	130,302		8,168	9.1	1.07
CHILLED WATER RESET	2381	936	4,031		101	9.3	1.05
CHILLED WATER RESET	1485	936	4,012		100	9.3	1.04
CHILLER WASTE HEAT REC.	2724	7,549		1,808	560	13.5	1.03
CHILLED WATER RESET	2373	936	3,897		97	9.6	1.01
	TOTALS	**$620,831**	**1,726,714**	**88,432**	**$99,300**	**6.3**	

Figure ES5.2-2 (4 of 4)

5.3 ECOS REJECTED:

Rejected ECOs are those with SIRs less than 1.0. Rejected boiler ECOs are shown in Figure ES5.3-1. Rejected chiller ECOs are shown in Figure ES53-2.

FIGURE ES5.3-1

BOILER ECOS REJECTED

ECO DESCRIPTION	BOILER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	PAGE #
ENERGY EFFICIENT MOTORS	1486	564	45	12.6	0.91	F - 37
OXYGEN TRIM SYSTEM	6580-1	21,186	1,119	18.9	0.90	F - 140
BOILER REPLACEMENT	1725-1	183,815	8,298	22.2	0.77	F - 90
ECONOMIZER INSTALLATION	1725-1	24,671	1,318	18.7	0.74	F - 148
BOILER REPLACEMENT	2780-2	183,815	7,069	26.0	0.66	F - 96
ENERGY EFFICIENT MOTORS	1486	507	27	18.9	0.61	F - 33
ENERGY EFFICIENT MOTORS	852	1,654	88	18.8	0.61	F - 29
ENERGY EFFICIENT MOTORS	852	1,288	68	19.0	0.60	F - 25
OXYGEN TRIM SYSTEM	1486-2	21,186	724	29.3	0.59	F - 123
OXYGEN TRIM SYSTEM	1486-1	21,186	683	31.0	0.55	F - 120
BOILER REPLACEMENT	2780-1	183,815	5,608	32.8	0.52	F - 93
ENERGY EFFICIENT MOTORS	6580	564	23	24.6	0.47	F - 77
ENERGY EFFICIENT MOTORS	5943	676	27	25.3	0.46	F - 65
ENERGY EFFICIENT MOTORS	5943	1,113	41	27.4	0.42	F - 61
BOILER REPLACEMENT	852-1	501,313	11,382	44.0	0.39	F - 81
BURNER REPLACEMENT	2780-1	71,616	2,027	35.3	0.39	F - 117
BOILER RESIZING	852	1,312,964	28,601	45.9	0.37	F - 160
ENERGY EFFICIENT MOTORS	5943	3,664	62	58.7	0.36	F - 69
ENERGY EFFICIENT MOTORS	1725	564	17	33.8	0.34	F - 41
BOILER REPLACEMENT	852-2	501,313	9,442	53.1	0.32	F - 84
BURNER REPLACEMENT	1725-1	71,616	1,528	46.9	0.30	F - 114
ENERGY EFFICIENT MOTORS	5943	2,518	65	40.0	0.29	F - 73
ENERGY EFFICIENT MOTORS	2780	676	17	39.5	0.29	F - 53
BOILER REPLACEMENT	852-3	501,313	7,807	64.2	0.27	F - 87
ENERGY EFFICIENT MOTORS	2780	1,113	26	42.7	0.27	F - 49
BURNER REPLACEMENT	2780-2	71,616	1,284	55.8	0.25	F - 117
ENERGY EFFICIENT MOTORS	1725	507	10	50.7	0.23	F - 45
BURNER REPLACEMENT	852-2	162,330	2,308	70.3	0.20	F - 108
BURNER REPLACEMENT	852-1	162,330	2,329	69.7	0.20	F - 105
AIR PREHEATER	1725-1	84,891	1,318	64.4	0.19	F - 154
ENERGY EFFICIENT MOTORS	2780	507	8	63.3	0.18	F - 57
SUMMER BOILER	1486	51,027	197	259.0	0.07	F - 157
BOILER REPLACEMENT	6580-1	165,463	534	309.9	0.06	F - 99
BOILER REPLACEMENT	6580-2	165,463	612	270.4	0.06	F - 102
ECONOMIZER INSTALLATION	1486-1	20,220	88	229.8	0.06	F - 145
OXYGEN TRIM SYSTEM	6580-3	21,186	10	2118.6	0.01	F - 143
AIR PREHEATER	1486-1	84,891	88	964.7	0.01	F - 151

FIGURE ES5.3-2

CHILLER ECOs REJECTED

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
CHILLER WASTE HEAT RECOVERY	6597	7,549	539	14.0	0.99	E -602
REPLACEMENT CHILLER	5942	26,300	2,654	9.9	0.98	E -385
CHILLED WATER RESET	2380	936	93	10.1	0.97	E -837
CHILLED WATER RESET	2377	936	89	10.5	0.93	E -825
REPLACEMENT CHILLER	2381	55,946	5,264	10.6	0.92	E -329
REPLACEMENT CHILLER	2373	55,946	4,954	11.3	0.86	E -297
ENERGY EFFICIENT MOTORS	1118	789	58	13.7	0.84	E -225
ENERGY EFFICIENT MOTORS	296	676	49	13.8	0.83	E -213
REPLACEMENT CHILLER	2380	55,946	4,556	12.3	0.79	E -325
CHILLED WATER RESET	6010	936	76	12.3	0.79	E -873
ENERGY EFFICIENT MOTORS	297	1,113	75	14.9	0.77	E -217
ENERGY EFFICIENT MOTORS	1117	564	38	14.8	0.77	E -221
CHILLED WATER RESET	5921	936	71	13.1	0.74	E -865
REPLACEMENT CHILLER	2377	55,946	4,202	13.3	0.73	E -313
REPLACEMENT CHILLER	1485	66,372	4,817	13.8	0.71	E -285
CHILLED WATER RESET	5916	936	68	13.7	0.71	E -845
CHILLED WATER RESET	2374	936	66	14.2	0.69	E -813
CHILLED WATER RESET	5922	936	66	14.2	0.69	E -869
CHILLED WATER RESET	2379	936	66	14.1	0.69	E -833
CHILLED WATER RESET	1475	936	66	14.1	0.69	E -781
CHILLED WATER RESET	2376	936	65	14.3	0.68	E -821
CHILLED WATER RESET	5919	936	64	14.7	0.67	E -857
CHILLED WATER RESET	1468	936	64	14.6	0.67	E -773
REPLACEMENT CHILLER	1474	91,900	6,287	14.6	0.67	E -265
REPLACEMENT CHILLER	1118	91,900	6,191	14.8	0.66	E -257
CHILLED WATER RESET	2375	936	62	15.0	0.65	E -817
REPLACEMENT CHILLER	6010	43,977	2,875	15.3	0.64	E -393
REPLACEMENT CHILLER	1482	91,900	5,824	15.8	0.62	E -277
CHILLED WATER RESET	5920	936	60	15.6	0.62	E -861
REPLACEMENT CHILLER	6289	58,023	3,618	16.0	0.61	E -413
CHILLED WATER RESET	6011	936	56	16.8	0.58	E -877
CHILLED WATER RESET	2378	936	56	16.7	0.58	E -829
REPLACEMENT CHILLER	296	66,372	3,649	18.2	0.54	E -237
REPLACEMENT CHILLER	5921	43,977	2,433	18.1	0.54	E -373
REPLACEMENT CHILLER	4770	178,224	9,879	18.0	0.54	E -349
ENERGY EFFICIENT MOTORS	5101	507	23	22.1	0.52	E -233
CHILLED WATER RESET	6015	936	50	18.8	0.52	E -881
REPLACEMENT CHILLER	297	55,946	2,920	19.2	0.51	E -241

Figure ES5.3-2 (1 of 2)

FIGURE ES5.3-2

CHILLER ECOS REJECTED

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR	REPORT PAGE #
REPLACEMENT CHILLER	5917	43,977	2,156	20.4	0.48	E -357
REPLACEMENT CHILLER	5916	43,977	2,156	20.4	0.48	E -353
REPLACEMENT CHILLER	5918	30,407	1,508	20.2	0.48	E -361
REPLACEMENT CHILLER	1484	91,900	4,217	21.8	0.45	E -281
REPLACEMENT CHILLER	5922	43,977	1,935	22.7	0.43	E -377
CHILLED WATER RESET	1483	936	138	24.7	0.40	E -793
REPLACEMENT CHILLER	5919	43,977	1,714	25.7	0.38	E -365
REPLACEMENT CHILLER	5949	48,990	1,930	25.4	0.38	E -389
REPLACEMENT CHILLER	6590	46,338	1,710	27.1	0.36	E -429
REPLACEMENT CHILLER	2379	55,946	2,079	26.9	0.36	E -321
REPLACEMENT CHILLER	1475	55,946	2,079	26.9	0.36	E -269
REPLACEMENT CHILLER	1117	48,990	1,733	28.3	0.35	E -253
REPLACEMENT CHILLER	2376	55,946	1,991	28.1	0.35	E -309
REPLACEMENT CHILLER	2374	55,946	2,035	27.5	0.35	E -301
WATERSIDE ECONOMIZER	SAMPLE	2,300	92	25.0	0.35	E -885
ENERGY EFFICIENT MOTORS	2385	404	12	34.9	0.34	E -229
REPLACEMENT CHILLER	2385	55,946	1,978	28.3	0.34	E -333
REPLACEMENT CHILLER	6554	47,323	1,572	30.1	0.32	E -425
REPLACEMENT CHILLER	5920	43,977	1,382	31.8	0.31	E -369
REPLACEMENT CHILLER	6012	46,338	1,416	32.7	0.30	E -401
REPLACEMENT CHILLER	2375	55,946	1,725	32.4	0.30	E -305
REPLACEMENT CHILLER	6017	43,977	1,272	34.6	0.28	E -409
VARIABLE SPEED FAN	SAMPLE	2,300	60	38.0	0.23	E -892
REPLACEMENT CHILLER	6011	43,977	995	44.2	0.22	E -397
REPLACEMENT CHILLER	1486	85,281	1,946	43.8	0.22	E -289
REPLACEMENT CHILLER	5940	46,338	1,003	56.2	0.21	E -381
CHILLED WATER RESET	5918	936	20	47.3	0.21	E -853
REPLACEMENT CHILLER	2378	55,946	1,150	48.6	0.20	E -317
REPLACEMENT CHILLER	298	55,946	1,150	48.6	0.20	E -245
REPLACEMENT CHILLER	4250	58,023	1,050	55.3	0.18	E -345
REPLACEMENT CHILLER	4249	58,023	1,092	53.1	0.18	E -341
CHILLED WATER STORAGE	SAMPLE	172,800	3,504	49.0	0.16	E -896
AUTOMATIC TUBE CLEANERS	SAMPLE	16,717	189	88.0	0.11	E -899
REPLACEMENT CHILLER	6015	43,977	442	99.4	0.10	E -405
REPLACEMENT CHILLER	6597	58,023	398	145.7	0.07	E -433
REPLACEMENT CHILLER	6553	91,900	649	141.7	0.07	E -421
REPLACEMENT CHILLER	6544	91,900	605	152.0	0.06	E -417

Figure ES5.3-2 (2 of 2)

5.4 PROJECTS DEVELOPED:

Based on guidance received following the interim submittal of this report, selected ECOs were grouped into one ECIP project. Project documentation was submitted for reveiw and approved by the Louisville COE Project Manager and Ft. Knox in April 1992. Copies of project documentation can be found in Volume IV, Appendix C. Recommended ECOs included in project documentation are shown in Figures ES5.4-1 and ES5.4-2.

FIGURE ES5.4-1

RECOMMENDED BOILER PROJECTS - SORTED BY SIR

ECO DESCRIPTION	BOILER PLANT ID	INITIAL COST ($)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
			MILLION BTU	($)		
BLOWDOWN HEAT REC.	852	19,845	5,079	15,744	1.3	11.00
OXYGEN TRIM SYSTEM	5943-2	21,186	1,047	5,663	3.7	4.47
TURBULATOR INST.	1486-1	1,573	197	611	2.6	3.74
TURBULATOR INST.	1486-2	1,573	197	611	2.6	3.74
OXYGEN TRIM SYSTEM	5943-1	21,186	728	3,938	5.4	3.11
TURBULATOR INST.	6580-1	1,954	148	459	4.3	2.26
TURBULATOR INST.	6580-2	1,954	148	459	4.3	2.26
TURBULATOR INST.	1725-1	3,507	231	716	4.9	1.97
BLOWDOWN HEAT REC.	2780	13,427	548	1,698	7.9	1.75
OXYGEN TRIM SYSTEM	2780-1	21,186	649	2,013	10.5	1.62
BLOWDOWN HEAT REC.	1486	19,845	656	2,033	9.8	1.44
TURBULATOR INST.	2780-2	3,507	168	521	6.7	1.43
TURBULATOR INST.	2780-1	3,507	161	499	7.0	1.37
OXYGEN TRIM SYSTEM	1725-1	21,186	530	1,644	12.9	1.33
OXYGEN TRIM SYSTEM	2780-2	21,186	499	1,546	13.7	1.25
BLOWDOWN HEAT REC.	1725	15,442	385	1,194	12.9	1.07
TURBULATOR INST.	6580-3	1,016	36	112	9.1	1.06
BLOWDOWN HEAT REC.	6580	23,797	553	1,715	13.9	1.00
	TOTALS	**$216,877**	**11,960**	**$41,176**	**5.3**	

FIGURE ES5.4 - 2

RECOMMENDED CHILLER PROJECTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
				(THERMS)	($)		
CHW PUMP SHUTDOWN/EMS	1479	202	17,826		446	0.5	21.56
CHW PUMP MOTOR RESIZING	2376	564	27,764		995	0.6	20.14
CHW PUMP MOTOR RESIZING	2379	564	27,764		995	0.6	20.14
CHW PUMP MOTOR RESIZING	6289	564	27,647		992	0.6	20.08
CHW PUMP MOTOR RESIZING	1482	564	27,375		973	0.6	19.70
CHW PUMP MOTOR RESIZING	1484	564	27,336		971	0.6	19.66
CHW PUMP SHUTDOWN/EMS	6389	202	12,070		302	0.7	14.60
CHW PUMP SHUTDOWN/EMS	5942	202	12,094		302	0.7	14.60
CHW PUMP SHUTDOWN/EMS	5940	202	12,094		302	0.7	14.60
CHW PUMP MOTOR RESIZING	1483	564	16,991		728	0.8	12.59
CHW PUMP MOTOR RESIZING	2380	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2375	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2373	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	298	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	297	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2374	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	1475	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	2377	564	16,913		723	0.8	12.50
CHW PUMP MOTOR RESIZING	1485	564	16,855		720	0.8	12.45
CHW PUMP MOTOR RESIZING	1474	564	16,485		700	0.8	12.10

FIGURE ES5.4 - 2

RECOMMENDED CHILLER PROJECTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
				(THERMS)	($)		
CHW PUMP MOTOR RESIZING	1486	564	16,213		685	0.8	11.84
CHW PUMP SHUTDOWN/EMS	5917	202	9,200		230	0.9	11.12
CHW PUMP SHUTDOWN/EMS	2381	202	9,200		230	0.9	11.12
CHW PUMP SHUTDOWN/EMS	296	202	9,200		230	0.9	11.12
CHW PUMP SHUTDOWN/EMS	853	202	9,200		230	0.9	11.12
CHW PUMP MOTOR RESIZING	6554	507	13,668		485	1.0	10.92
CHW PUMP MOTOR RESIZING	6544	507	13,376		469	1.1	10.56
CHW PUMP SHUTDOWN/EMS	5918	202	7,644		191	1.1	9.23
CHW PUMP MOTOR RESIZING	2378	564	11,081		471	1.1	9.06
CHW PUMP SHUTDOWN/EMS	1483	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2380	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	297	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1474	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	6017	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2377	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2375	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	298	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1486	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1482	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1475	202	6,185		155	1.3	7.49

Figure ES5.4-2 (2 of 6)

FIGURE ES5.4 - 2

RECOMMENDED CHILLER PROJECTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
				(THERMS)	($)		
CHW PUMP SHUTDOWN/EMS	2373	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	2374	202	6,185		155	1.3	7.49
CHW PUMP SHUTDOWN/EMS	1485	202	6,185		155	1.3	7.49
CHILLER SHUTDOWN/EMS	1118	3,006	81,051		2,026	1.5	6.58
CHW PUMP MOTOR RESIZING	1468	564	5,540		236	1.7	5.70
CHW PUMP MOTOR RESIZING	6011	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5919	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	6015	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5922	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	6010	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5921	404	5,103		211	1.9	5.10
CHW PUMP MOTOR RESIZING	5920	404	5,103		211	1.9	5.10
CHILLER SHUTDOWN/EMS	6012	3,006	62,803		1,570	1.9	5.10
CHW PUMP MOTOR RESIZING	5916	404	5,103		211	1.9	5.10
CHW PUMP SHUTDOWN/EMS	2378	202	3,807		95	2.1	4.59
CHILLER WASTE HEAT RECOVERY	1485	7,549		7,026	2,234	3.4	4.10
CHILLER SHUTDOWN/EMS	2724	3,006	41,738		1,252	2.4	4.06
CHW PUMP SHUTDOWN/EMS	6015	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5920	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5922	202	2,570		64	3.1	3.09

Figure ES5.4-2 (3 of 6)

FIGURE ES5.4 - 2

RECOMMENDED CHILLER PROJECTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS		PAYBACK (YEARS)	SIR
				(THERMS)	($)		
CHW PUMP SHUTDOWN/EMS	6010	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	1468	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	6011	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5919	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5916	202	2,570		64	3.1	3.09
CHW PUMP SHUTDOWN/EMS	5921	202	2,570		64	3.1	3.09
CHILLER SHUTDOWN/EMS	5101	3,006	37,024		926	3.2	3.01
CHILLER WASTE HEAT RECOVERY	1474	7,549		5,116	1,586	4.8	2.91
CHILLER SHUTDOWN/EMS	4250	3,006	24,453		874	3.4	2.84
CHILLER SHUTDOWN/EMS	9261	3,006	34,407		860	3.5	2.79
CHILLER WASTE HEAT RECOVERY	1482	7,549		4,834	1,499	5.0	2.75
CHW PUMP SHUTDOWN/EMS	6590	202	2,175		54	3.7	2.61
CHILLER WASTE HEAT RECOVERY	1484	7,549		4,318	1,338	5.6	2.46
CHILLER WASTE HEAT RECOVERY	1486	7,549		4,116	1,292	5.8	2.37
CHILLED WATER RESET	296	936	8,763		219	4.3	2.28
CHILLER SHUTDOWN/EMS	4249	3,006	17,681		704	4.3	2.28
CHILLER WASTE HEAT RECOVERY	1118	7,549		3,865	1,198	6.3	2.20
CHW PUMP SHUTDOWN/EMS	2385	202	1,740		44	4.6	2.13
CHW PUMP SHUTDOWN/EMS	5949	202	1,740		44	4.6	2.13
CHILLER WASTE HEAT RECOVERY	2381	7,549		3,583	1,111	6.8	2.04

Figure ES5.4-2 (4 of 6)

FIGURE ES5.4 - 2

RECOMMENDED CHILLER PROJECTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS (THERMS)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR
CHILLER WASTE HEAT RECOVERY	2373	7,549		3,463	1,074	7.0	1.97
CHILLER WASTE HEAT RECOVERY	6289	7,549		3,440	1,066	7.1	1.96
CHILLED WATER RESET	297	936	7,534		188	5.0	1.96
CHILLED WATER RESET	853	936	7,294		182	5.1	1.90
CHILLER WASTE HEAT RECOVERY	2380	7,549		3,310	1,026	7.4	1.88
CHILLER WASTE HEAT RECOVERY	2377	7,549		3,173	984	7.7	1.81
CHILLER WASTE HEAT RECOVERY	296	7,549		3,115	966	7.8	1.77
CHILLER WASTE HEAT RECOVERY	1483	7,549		3,046	944	8.0	1.73
CHILLER WASTE HEAT RECOVERY	2385	7,549		2,703	838	9.0	1.54
CHILLER WASTE HEAT RECOVERY	297	7,549		2,679	830	9.1	1.53
CHILLED WATER RESET	1474	936	5,756		144	6.5	1.50
CHILLED WATER RESET	298	936	5,615		140	6.7	1.46
CHILLED WATER RESET	1482	936	5,439		136	6.9	1.42
REPLACEMENT CHILLER	1479	55,946	140,765		7,785	7.2	1.36
CHILLER WASTE HEAT RECOVERY	5949	7,549		2,372	735	10.3	1.35
CHILLER WASTE HEAT RECOVERY	6544	7,549		2,355	730	10.3	1.34
CHILLER WASTE HEAT RECOVERY	2379	7,549		2,354	730	10.3	1.34
CHILLER WASTE HEAT RECOVERY	1475	7,549		2,354	730	10.3	1.34
CHILLER WASTE HEAT RECOVERY	2374	7,549		2,377	725	10.4	1.33
CHILLED WATER RESET	1479	936	5,125		128	7.3	1.33

Figure ES5.4-2 (5 of 6)

FIGURE ES5.4 - 2

RECOMMENDED CHILLER PROJECTS - SORTED BY SIR

ECO DESCRIPTION	CHILLER PLANT ID	INITIAL COST ($)	(KWH)	ANNUAL SAVINGS (THERMS)	ANNUAL SAVINGS ($)	PAYBACK (YEARS)	SIR
CHILLER WASTE HEAT RECOVERY	2376	7,549		2,320	719	10.5	1.32
CHILLER WASTE HEAT RECOVERY	6553	7,549		2,320	719	10.5	1.32
CHILLER WASTE HEAT RECOVERY	1720	7,549		2,233	692	10.9	1.27
CHILLED WATER RESET	1484	936	4,858		121	7.7	1.26
CHILLER WASTE HEAT RECOVERY	2375	7,549		2,218	688	11.0	1.26
CHILLED WATER RESET	5917	936	4,703		118	8.0	1.23
CHILLED WATER RESET	1486	936	4,687		117	8.0	1.22
REPLACEMENT CHILLER	1468	32,563	70,382		3,893	8.4	1.17
CHILLER WASTE HEAT RECOVERY	298	7,549		1,996	619	12.2	1.14
CHILLER WASTE HEAT RECOVERY	2378	7,549		1,996	619	12.2	1.14
CHILLER WASTE HEAT RECOVERY	1117	7,549		1,990	617	12.2	1.13
CHILLER WASTE HEAT RECOVERY	6554	7,549		1,952	605	12.5	1.11
REPLACEMENT CHILLER	1720	91,900	189,840		9,539	9.6	1.09
REPLACEMENT CHILLER	853	91,900	182,621		10,100	9.1	1.07
REPLACEMENT CHILLER	2724	74,157	130,302		8,168	9.1	1.07
CHILLED WATER RESET	2381	936	4,031		101	9.3	1.05
CHILLED WATER RESET	1485	936	4,012		100	9.3	1.04
CHILLER WASTE HEAT RECOVERY	2724	7,549		1,808	560	13.5	1.03
CHILLED WATER RESET	2373	936	3,897		97	9.6	1.01
	TOTALS	**$620,831**	**1,726,714**	**88,432**	**$99,300**	**6.3**	

Figure ES5.4-2 (6 of 6)

5.5 OPERATION AND MAINTENANCE RECOMMENDATIONS:

Recommended improvements in Operation and Maintenance (O&M) for boilers include improved water treatment, steam pressure and hot water temperature reduction, prevent air leakage, and equipment optimization. These improvements are described in detail in Volume II, Section 3 of this report, pages 3-1 through 3-12.

Recommended chiller O&Ms include water treatment, repair of leaks, refrigerant recharges, repair of defective chiller controls, and repair of insulation. These O&Ms are described in detail in Volume II, Section 3 of this report, pages 3-12 through 3-37.

6.0 ENERGY AND COST SAVINGS

As was shown in Section 4.0, current annual energy consumption and costs for operation of boilers and chillers are as follows:

FIGURE ES6-1

CURRENT ANNUAL ENERGY CONSUMPTION AND COST

ANNUAL ENERGY CONSUMPTION			ANNUAL ENERGY COST
NATURAL GAS (Million Btu)	#2 FUEL OIL (Million Btu)	ELECTRICITY (Million Btu)	
288,816	52,607	26,716	$1,709,986

6.1 TOTAL POTENTIAL ENERGY AND COST SAVINGS:

As was shown in Section 5.2, total potential energy and cost savings by implementing all recommended ECMs are as follows:

FIGURE ES6.1-1

TOTAL POTENTIAL ENERGY AND COST SAVINGS

ANNUAL ENERGY SAVINGS			ANNUAL ENERGY SAVINGS
NATURAL GAS (Million Btu)	#2 FUEL OIL (Million Btu)	ELECTRICITY (Million Btu)	
19,028	1,775	5,893	$140,476

6.2 PERCENTAGE OF ENERGY CONSERVED:

Energy and costs conserved by implementation of all recommended ECMs can be calculated as percentages of current annual consumption as follows:

FIGURE ES6.2-1

PERCENTAGE OF ENERGY AND COSTS CONSERVED

ANNUAL ENERGY SAVINGS				ANNUAL ENERGY COST SAVINGS
NATURAL GAS (Million Btu)	#2 FUEL OIL (Million Btu)	ELECTRICITY (Million Btu)	TOTAL	
7%	3%	22%	7%	8%

6.3 CURRENT AND PROJECTED ENERGY USE AND COSTS:

Following is a summary table of current and projected energy use and costs:

FIGURE ES6.3-1

CURRENT AND PROJECTED ENERGY USE AND COSTS BY BOILERS AND CHILLERS

	ANNUAL ENERGY SAVINGS				ANNUAL ENERGY COST SAVINGS
	NATURAL GAS (Million Btu)	#2 FUEL OIL (Million Btu)	ELECTRICITY (Million Btu)	TOTAL	
CURRENT	288,816	52,607	26,716	368,139	$1,709,986
PROJECTED	269,788	50,832	20,823	341,443	$1,569,510
SAVINGS	19,028	1,775	5,893	26,696	$140,476